State of North Carolina
Cooperating Technical State
Mapping Activity Statement

Agreement D—Digital Elevation Data Development for Six Eastern River Basins

In accordance with the Cooperating Technical State (CTS) Memorandum of Agreement dated September 15, 2000, between the State of North Carolina and the Federal Emergency Management Agency (FEMA), Agreement D is as follows:

1. **Objective and Scope:** The objective of this Agreement is to acquire digital topographic data of the six eastern river basins in the State of North Carolina using airborne Light Detection and Ranging (LIDAR). Variably spaced, bare-earth digital topographic data in ASCII point file format will be combined with imagery (either flown concurrently with the LIDAR data collection or obtained from existing digital orthophotos) to establish a Triangulated Irregular Network (TIN) to include selected breaklines to be used for hydraulic modeling. Uniformly spaced Digital Elevation Models (DEMs) will be generated in multiple file formats for hydrologic and hydraulic modeling and other State and County applications using ARC/INFO and other GIS software. The primary goal is to use these data for floodplain modeling and mapping for counties and communities in the six eastern river basins in accordance with Mapping Activity Statement E between the State of North Carolina and FEMA. This Mapping Activity Statement Agreement is for the six eastern river basins in the State of North Carolina: Lumber, Cape Fear, White Oak, Neuse, Tar-Pamlico, and Pasquotank.

2. **Period of Performance:** This Mapping Activity will begin in December 2000 and continue through March 31, 2002. This Mapping Activity Agreement may be terminated at the option of FEMA or the State of North Carolina in accordance with the provisions of the September 15, 2000, CTS Memorandum of Agreement.

3. **Funding/Cost-Sharing:** Funding will be in accordance with CTS Funding Agreement No. 1.

4. **Tasks:** The following tasks are to be performed by the State and/or its contractors:

   - Task 1: LIDAR Data Acquisition. The first task requires calibration of the LIDAR system; acquisition of the raw data (airborne GPS, inertial measuring unit, and last-return LIDAR data) of the specified geographic area suitable for ASCII point files and TIN and DEM requirements listed below; and verification that all data are complete and usable. The calibration shall include establishment of a test course at each airport used for data acquisition flights; data are to be collected over this course during each flight. Furthermore, data acquisition will include cross-flights sufficient to validate the LIDAR data and detect systematic errors for system calibration. Acquisition of supplemental imagery and/or first-return and intermediate-return LIDAR data is optional. A data file for each flight conducted will contain GPS time tags associated with the XYZ position of

the aircraft during the flight and the associated GPS quality factor for each position. The State's contractors will have the flexibility of developing flight plans to create the necessary point density to meet the posting and accuracy requirements specified below and minimize the occurrence of data voids or gaps in the data sets.

- Task 2: Generation of Bare-Earth ASCII Files. This task requires the post-processing of the LIDAR data and production of the bare-earth ASCII point file of XYZ coordinates. The State's contractors will perform automated and manual post-processing of the raw LIDAR data to remove laser points that impinged on bridges, buildings, dense non-penetrated vegetation, and other features that do not represent the bare earth. The contractors will then produce a bare-earth ASCII point file of orthometric heights with coordinates produced to the NAD83 horizontal datum, 1995 HARN adjustment, and the NAVD88 vertical datum. North Carolina State Plane coordinates will be used, and all horizontal and vertical coordinates will be in meters to three decimal places.

- Task 3: Generation of TIN and Breaklines. This task requires the creation of a TIN (ESRI TIN format) to include supplemental breaklines (ESRI breakline coverage as 3-D points, lines, or polygons) that form additional TIN edges. For the breaklines, the State will use available imagery to establish edge of water lines and approximate location of breaklines at the tops and bottoms of major stream banks to enable hydraulic modeling of the stream channel geometry. This data set will be in ESRI TIN format because ESRI's ARC/INFO is commonly used for semi-automated hydraulic modeling. Successful completion of Task 3 is contingent on acceptance of the TIN by the North Carolina Geodetic Survey (NCGS). Before the TIN is accepted for hydraulic modeling, its accuracy will be independently assessed by the NCGS to ensure that accuracy standards have been satisfied and to ensure the data are suitable for hydraulic modeling. This assessment may dictate the reprocessing of data and/or supplemental data acquisition.

- Task 4: Development of DEMs in ESRI Grid Format. This task requires the production of a uniformly spaced 5m x 5m DEM (in ESRI GRID Float format) suitable for hydrologic modeling and diverse requirements of the State and counties.

- Task 5: Development of DEMs in Three Additional File Formats. Once the DEM grid has been cleaned of artifacts, other 5m x 5m uniformly spaced DEMs will be produced for non-ESRI product users in three additional file formats: (1) ASCII point file format (State Plane coordinates); (2) ASCII point file format (UTM coordinates); and (3) BIL file format (State Plane coordinates).

- Task 6: Preparation of Project Report. Task 6 requires the preparation of a Project Report for each river basin that documents the mission dates, times, flight altitude, airspeed, flight lines, scan angle, scan rate, laser pulse rates, weather conditions, and other information deemed pertinent in accordance with Table A4B-1 of Appendix 4B to FEMA 37 (www.fema.gov/mit/tsd/lidar_4b.htm). In the Project Reports, the State contractors must provide evidence that the total LIDAR system was regularly calibrated for the purpose of identifying and correcting systematic errors. The reports must explain how calibration was checked or validated during the duration of the data acquisition phase by using the test course and cross-flights and explain how calibration

data were used in post-processing. The reports will also explain procedures used for post-processing and generation of TINs, breaklines, and DEMs; difficulties encountered; and steps taken to resolve discrepancies.

5. **Standards:**

- The LIDAR data are to be acquired during leaf-off and favorable weather conditions to produce a bare-earth TIN to be used for hydraulic modeling and bare-earth DEMs, in multiple file formats, to be used for hydrologic modeling and other State and County activities. Data should not be acquired during flooding conditions or with snow, other than a light dusting; low-water conditions are highly desirable but not mandatory.

- A bare-earth ASCII point file represents variably spaced LIDAR reflections from the ground or from low vegetation on the ground, and not from a vegetation canopy or structures. The bare-earth ASCII point file from Task 2 and the resultant TIN from Task 3 should have a vertical accuracy of 40 cm or better at the 95% confidence level for coastal counties, and 50 cm or better for non-coastal counties. To achieve this vertical accuracy, consistent with the National Standard for Spatial Data Accuracy, the ASCII point file and TIN should have a vertical RMSE of 20 cm or less for coastal counties and 25 cm or less for non-coastal counties in each of the major vegetation categories within the floodplain being studied, after correction for systematic errors.

- To check the vertical accuracy of the TIN in accordance with Appendix 4B of FEMA 37, "Airborne Light Detection and Ranging Systems," the NCGS will perform an independent accuracy assessment of the bare-earth TIN for each county by selecting and surveying a minimum of 20 check points in each of three or more major vegetation categories that predominate within the floodplain being studied. Check points will be selected on terrain that is flat or of uniform slope for 5 meters in all directions, avoiding check points that are near breaklines with changing slope. Check points will be surveyed by combination of GPS and conventional surveys as necessary to establish check points in the interior of forested areas. TIN linear interpolation will be used by the NCGS to compare surveyed elevations with interpolated elevations from surrounding TIN points. The NCGS will discard no more than 5% of check points in the RMSE calculations to account for uncleaned artifacts. If RMSE values exceed 20 cm in coastal counties or 25 cm in non-coastal counties for any of the vegetation categories, an assessment will be made by the NCGS, in coordination with FEMA, to determine if the data are usable for their intended purpose, or if additional steps are necessary to produce an acceptable data set.

- The DEMs in all file formats (Tasks 4 and 5) will have uniform 5-meter point spacing where horizontal State Plane coordinates are whole-meters ending with 0 or 5; the horizontal datum is NAD83, 1995 HARN adjustment. Vertical coordinates are in meters to three decimal places; the vertical datum is NAVD88.

6. **Schedule and Milestones:** The following sequential tasks will be undertaken to develop the TINs and DEMs needed for hydrologic and hydraulic modeling and floodplain mapping:

- LIDAR data acquisition

- Generation of bare-earth ASCII files
- Generation of TIN and breaklines
- Development of DEMs in ESRI Grid (State Plane) format
- Development of DEMs in ASCII Point File (State Plane and UTM) and BIL (State Plane) formats
- Preparation of basin Project Reports

The TINs shall be completed by April 1, 2001, for the Lumber, White Oak, and Tar-Pamlico River basins and by June 30, 2001, for the Cape Fear, Neuse, and Pasquotank River basins. The DEMs in all file formats and final Project Reports shall be completed by May 1, 2001, for the Lumber, White Oak, and Tar-Pamlico River basins and by July 31, 2001, for the Cape Fear, Neuse, and Pasquotank River basins.

7. **Certification:** A Professional Engineer or Licensed Land Surveyor will certify topographic information, in accordance with 44 CFR 65.5(c) and North Carolina General Statute 89C.

8. **Technical Assistance and Resources:** FEMA's Mapping Coordination Contractor, Dewberry & Davis LLC, will provide technical assistance in developing contractor Delivery Order proposal requests, setting up control networks, assessing DEM data accuracy, and merging ground surveys with remote sensing data to fill data voids. FEMA will provide the State of North Carolina any new or updated guidelines, standards, and requirements associated with both contract work and programmatic direction.

   The NASA Office of Earth Science may provide an independent LIDAR test strip, from the North Carolina border with South Carolina to the border with Virginia, that runs through all six basins. As envisioned, this strip would be flown and post-processed by the U.S. Army Topographic Engineering Center to produce a strip of bare-earth elevation points. This would be an optional bonus tool for assessing the accuracy of the LIDAR data, as opposed to a mandatory requirement.

9. **Contractors:** Contractors will be used by the State of North Carolina for this activity. Contractors will be licensed to practice in the State of North Carolina as required by North Carolina General Statute 89C. Independent contractors will be used by the State of North Carolina to assist in the acquisition of topographic data and in QA/QC.

10. **Quality Assurance/Quality Control (QA/QC) Procedures:** The NCGS will conduct control surveys using differential GPS and traditional survey techniques to ensure the accuracy of the TIN data, as described under the "Standards" section of this Agreement.

11. **Reporting:** Regular progress reports will be provided during CTS Committee meetings. The final Project Report prepared by the State's contractor(s) will also be provided to the CTS Committee for review and concurrence.

12. **Points of Contact:** The FEMA Project Manager is Laura Algeo, and the CTS Program Director is John Dorman, or subsequent personnel of comparable experience who are appointed to fulfill these responsibilities.

Each party has caused this Mapping Activity Statement to be executed by its duly authorized representatives.

John K Dorman — 05/25/01

John K. Dorman, Program Director
North Carolina Office of State Budget, Planning, and Management — Date

Laura Algeo — 07/16/01

Laura Algeo, Project Manager
Federal Emergency Management Agency — Date

05/11/01

Doug Bellomo, Project Officer
Federal Emergency Management Agency — Date